

RESIDENTIAL ACM APPENDIX RB

Appendix RB – Interior Mass Capacity

RB.1 Scope and Purpose

Interior Mass Capacity (IMC) is a measure of the total thermal mass in a low-rise residential building. IMC is used to determine if a building qualifies as a high mass building. Credit for thermal mass in the *Proposed Design* may only be considered when the *Proposed Design* qualifies as a high mass building. A high mass building is one with thermal mass equivalent to having 30 percent of the conditioned slab floor exposed and 15% of the conditioned non-slab floor exposed two inch thick concrete.

RB.2 Calculating Interior Mass Capacity (IMC)

The IMC for the building is calculated using Equation RB1. The IMC for the building is the sum of the area of each mass material multiplied times its Unit Interior Mass Capacity (UIMC). Table RB-1, Table RB-2, and Table RB-3 give UIMC values for a number of common thermal mass materials. This method allows for multiple mass types common in low-rise residential construction.

$$\text{Equation RB-1} \quad \text{IMC} = \sum_{i=1}^N A_i \times \text{UIMC}_i$$

where

IMC = Interior thermal mass of the building

A_i = Surface area of the i^{th} material

UIMC_i = Unit Interior Mass Capacity (UIMC) of the i^{th} material selected from Table RB-1, Table RB-2, and Table RB-3

N = Number of thermal mass materials in the *Proposed Design*

RB.3 IMC Threshold for a High Mass Building

In order to qualify as a high mass building, the *Proposed Design* must have an IMC greater than or equal to that determined from Equation RD2. The IMC threshold is based on 30% of the conditioned slab area (CSA) being exposed (UIMC=4.6); 70% of the CSA being covered (UIMC=1.8); and 15% of the conditioned non-slab floor area as exposed two inch thick concrete (UIMC=2.5).

$$\begin{aligned} \text{Equation RB-2} \quad \text{IMC}_{\text{Threshold}} &= 0.3 \times 4.6 \times \text{CSA} + 0.7 \times 1.8 \times \text{CSA} + 0.15 \times 2.5 \times (\text{CFA} - \text{CSA}) \\ &= 2.640 \times \text{CSA} + 0.375 \times (\text{CFA} - \text{CSA}) \end{aligned}$$

where:

CSA = Conditioned Slab floor Area

CFA = Total Conditioned Floor Area

Table RB-1 – Interior Mass UIMC Values: Interior Mass¹¹- Surfaces Exposed on One Side¹³

<u>Material</u>	<u>Surface Condition</u>	<u>Mass Thickness (inches)</u>	<u>Unit Interior Mass Capacity</u>
<u>Concrete</u> <u>Slab-on-Grade and</u> <u>Raised Concrete Floors</u>	<u>Exposed</u> ¹	<u>2.00</u>	<u>3.6</u>
		<u>3.50</u>	<u>4.6</u>
		<u>6.00</u>	<u>5.1</u>
	<u>Covered</u> ²	<u>2.00</u>	<u>1.6</u>
		<u>3.50</u>	<u>1.8</u>
		<u>6.00</u>	<u>1.9</u>
<u>Lightweight</u> <u>Concrete</u> ⁹	<u>Exposed</u>	<u>0.75</u>	<u>1.0</u>
		<u>1.00</u>	<u>1.4</u>
		<u>1.50</u>	<u>2.0</u>
		<u>2.00</u>	<u>2.5</u>
	<u>Covered</u>	<u>0.75</u>	<u>0.9</u>
		<u>1.00</u>	<u>1.0</u>
		<u>1.50</u>	<u>1.2</u>
		<u>2.00</u>	<u>1.4</u>
<u>Solid Wood</u> ⁹	<u>Exposed</u>	<u>1.50</u>	<u>1.2</u>
		<u>3.00</u>	<u>1.6</u>
<u>Tile</u> ^{3,9}	<u>Exposed</u>	<u>0.50</u>	<u>0.8</u>
		<u>1.00</u>	<u>1.7</u>
		<u>1.50</u>	<u>2.4</u>
		<u>2.00</u>	<u>3.0</u>
<u>Masonry</u> ^{4,9}	<u>Exposed</u>	<u>1.00</u>	<u>2.0</u>
		<u>2.00</u>	<u>2.7</u>
		<u>4.00</u>	<u>4.2</u>
<u>Adobe</u> ⁹	<u>Exposed</u>	<u>4.00</u>	<u>3.8</u>
		<u>6.00</u>	<u>3.9</u>
		<u>8.00</u>	<u>3.9</u>
<u>Framed Wall</u>	<u>0.50" Gypsum</u>	<u>na</u>	<u>0.0</u>
	<u>0.63" Gypsum</u>	<u>na</u>	<u>0.1</u>
	<u>1.00" Gypsum</u>	<u>na</u>	<u>0.5</u>
	<u>0.88" Stucco</u>	<u>na</u>	<u>1.1</u>
<u>Masonry Infill</u> ⁷	<u>0.50" Gypsum</u>	<u>3.50</u>	<u>1.3</u>

Table RB-2 – Interior Mass UIMC Values: Interior Mass¹¹ - Surfaces Exposed on Two Sides^{5, 13}

<u>Material</u>	<u>Surface Condition</u>	<u>Mass Thickness (inches)</u>	<u>Unit Interior Mass Capacity</u>
<u>Partial Grout</u> <u>Masonry</u> ⁴	<u>Exposed</u> ¹	<u>4.00</u>	<u>6.9</u>
		<u>6.00</u>	<u>7.4</u>
		<u>8.00</u>	<u>7.4</u>
<u>Solid Grout</u> <u>Masonry</u> ^{4,6}	<u>Exposed</u>	<u>4.00</u>	<u>8.3</u>
		<u>6.00</u>	<u>9.2</u>
		<u>8.00</u>	<u>9.6</u>
<u>Adobe</u>	<u>Exposed</u>	<u>4.00</u>	<u>7.6</u>
		<u>12.00</u>	<u>7.8</u>
		<u>16.00</u>	<u>7.6</u>
<u>Solid Wood/</u> <u>Logs</u>	<u>Exposed</u>	<u>3.00</u>	<u>3.3</u>
		<u>4.00</u>	<u>3.3</u>
		<u>6.00</u>	<u>3.3</u>
		<u>8.00</u>	<u>3.3</u>
<u>Framed Wall</u>	<u>0.50" Gypsum</u>	<u>na</u>	<u>0.0</u>
	<u>0.63" Gypsum</u>	<u>na</u>	<u>0.2</u>
	<u>1.00" Gypsum</u>	<u>na</u>	<u>0.9</u>
	<u>0.88" Stucco</u>	<u>na</u>	<u>2.1</u>
<u>Masonry Infill</u> ⁷	<u>0.50" Gypsum</u>	<u>3.50</u>	<u>2.6</u>

Table RB-3 – Exterior Wall Mass UIMC Values¹³

<u>Material</u>	<u>Surface Condition</u>	<u>Mass Thickness (inches)</u>	<u>Wall U-value</u>	<u>Unit Interior Mass Capacity</u>
<u>Solid Wood/</u>	<u>Exposed</u> ¹	<u>3.00</u>	<u>0.22</u>	<u>0.7</u>
<u>Logs</u>		<u>4.00</u>	<u>0.17</u>	<u>0.9</u>
		<u>6.00</u>	<u>0.12</u>	<u>1.1</u>
		<u>8.00</u>	<u>0.093</u>	<u>1.2</u>
		<u>10.00</u>	<u>0.075</u>	<u>1.3</u>
		<u>12.00</u>	<u>0.063</u>	<u>1.3</u>
<u>Wood Cavity</u>	<u>Exposed</u>	<u>3.00</u> ¹²	<u>0.11</u>	<u>1.1</u>
<u>Wall</u> ¹²			<u>0.065</u>	<u>1.3</u>
			<u>0.045</u>	<u>1.4</u>
<u>Adobe</u>	<u>Exposed</u>	<u>8.00</u>	<u>0.35</u>	<u>2.1</u>
		<u>16.00</u>	<u>0.21</u>	<u>2.8</u>
		<u>24.00</u>	<u>0.15</u>	<u>3.1</u>
<u>Masonry</u>	<u>Framed Wall</u>	<u>4.00</u>	<u>0.10</u>	<u>na</u>
<u>Veneer</u> ⁴			<u>0.08</u>	<u>na</u>
			<u>0.06</u>	<u>na</u>
<u>Adobe</u>	<u>Framed Wall</u>	<u>4.00</u>	<u>0.10</u>	<u>na</u>
<u>Veneer</u>			<u>0.08</u>	<u>na</u>
			<u>0.06</u>	<u>na</u>
<u>Partial Grout</u>	<u>Exposed</u> ¹	<u>4.00</u>	<u>0.68</u>	<u>0.9</u>
<u>Masonry</u> ⁴			<u>0.58</u>	<u>1.0</u>
		<u>6.00</u>	<u>0.54</u>	<u>1.3</u>
			<u>0.44</u>	<u>1.5</u>
		<u>8.00</u>	<u>0.49</u>	<u>1.5</u>
			<u>0.38</u>	<u>1.7</u>
	<u>Furred</u> ¹⁰	<u>4.00</u>	<u>0.40</u>	<u>0.5</u>
			<u>0.30</u>	<u>0.5</u>
			<u>0.20</u>	<u>0.5</u>
			<u>0.10</u>	<u>0.5</u>
			<u>0.08</u>	<u>0.5</u>
		<u>6.00</u>	<u>0.40</u>	<u>0.9</u>
			<u>0.30</u>	<u>0.6</u>
			<u>0.20</u>	<u>0.5</u>
			<u>0.10</u>	<u>0.5</u>
			<u>0.08</u>	<u>0.5</u>
		<u>8.00</u>	<u>0.30</u>	<u>0.8</u>
			<u>0.20</u>	<u>0.5</u>
			<u>0.10</u>	<u>0.5</u>

0.08

0.5

Table RB-3: Exterior Wall Mass UIMC Values (continued)¹³

<u>Material</u>	<u>Surface Condition</u>	<u>Mass Thickness (inches)</u>	<u>Wall U-value</u>	<u>Unit Interior Mass Capacity</u>
<u>Solid Grout</u> <u>Masonry</u> ^{4,6}	<u>Exposed</u>	<u>4.00</u>	<u>0.79</u>	<u>1.0</u>
		<u>6.00</u>	<u>0.68</u>	<u>1.5</u>
		<u>8.00</u>	<u>0.62</u>	<u>1.8</u>
	<u>Furred</u> ¹⁰	<u>4.00</u>	<u>0.40</u>	<u>0.5</u>
			<u>0.30</u>	<u>0.5</u>
			<u>0.20</u>	<u>0.5</u>
			<u>0.10</u>	<u>0.5</u>
			<u>0.08</u>	<u>0.5</u>
		<u>6.00</u>	<u>0.40</u>	<u>0.7</u>
			<u>0.30</u>	<u>0.5</u>
			<u>0.20</u>	<u>0.5</u>
			<u>0.10</u>	<u>0.5</u>
			<u>0.08</u>	<u>0.5</u>
		<u>8.00</u>	<u>0.40</u>	<u>0.8</u>
			<u>0.30</u>	<u>0.6</u>
			<u>0.20</u>	<u>0.5</u>
			<u>0.10</u>	<u>0.5</u>
			<u>0.08</u>	<u>0.5</u>

RB.4 Table Notes

1. "Exposed" means that the mass is directly exposed to room air or covered with a conductive material such as ceramic tile.
2. "Covered" includes carpet, cabinets, closets or walls.
3. The indicated thickness includes both the tile and the mortar bed, when applicable.
4. Masonry includes brick, stone, concrete masonry units, hollow clay tile and other masonry.
5. The unit interior mass capacity for surfaces exposed on two sides is based on the area of one side only.
6. "Solid Grout Masonry" means that all the cells of the masonry units are filled with grout.
7. The indicated thickness for masonry infill is for the masonry material itself.
8. Use the Exterior Mass value for calculating Exterior Wall Mass.
9. Mass located inside exterior walls or ceilings may be considered interior mass (exposed one side) when it is insulated on the exterior with at least R-11 insulation, or a total resistance of R-9 including framing effects.
10. "Furred" means that 0.50-inch gypsum board is placed on the inside of the mass wall separated from the mass with insulation or an air space.
11. When mass types are layered, e.g. tile over slab-on-grade or lightweight concrete floor, only the mass type with the greatest interior mass capacity may be accounted for, based on the total thickness of both layers.

12. This wall consists of 3 inches of wood on each side of a cavity. The cavity may be insulated as indicated by the U-value column.

13. Values based on properties of materials listed in 1993 ASHRAE Handbook of Fundamentals.

The *Interior Mass Capacity (IMC)* of a material is calculated by multiplying its *Area* times its *Unit Interior Mass Capacity (UIMC)* using Equation I-1. Tables 3-2a, 3-2b and 3-3 list the UIMCs for a number of thermal mass materials. This method allows for multiple mass types in both raised-floor and slab-on-grade construction.

The *Interior Mass Capacity* for the *Standard Design* shall be determined as 20 percent of the *Proposed Design's* conditioned slab floor as 3.5 inch thick exposed slab (UIMC=4.6), 80% of the conditioned slab as 3.5 inch thick rug-covered slab (UIMC=1.8), and 5% of the *Proposed Design's* conditioned nonslab floor area as exposed 2 inch thick concrete (UIMC=2.5). If the user does not specify a high mass design, the *Interior Mass Capacity* of the *Proposed Design* shall be the same as for the *Standard Design*. If the user specifies a high mass design with an *Interior Mass Capacity* greater than the high mass threshold, the user is allowed to model the mass specified in the *Proposed Design*. The high mass threshold *Interior Mass Capacity* is determined as 30% of the conditioned floor area as exposed slab (UIMC=4.6), 70% of the conditioned slab floor area as rug-covered slab (UIMC=1.8), and 15% of the conditioned nonslab floor area as 2 inch thick concrete (UIMC=2.5).

EQUATION NO. I-1

CALCULATION OF INTERIOR MASS CAPACITY

$$IMC = [(A_1 \times UIMC_1) + (A_2 \times UIMC_2) \dots + (A_n \times UIMC_n)]$$

Where,

— A_n = Area of mass material n , and

— $UIMC_n$ = Unit Interior Mass Capacity of mass material n

Based on the UIMCs given above:

$$IMC_{threshold} = 2.64 \times CSA + 0.375 \times (CFA - CSA)$$

Where:

— CSA = Conditioned Slab floor Area

— CFA = total Conditioned Floor Area

Table 3-2a: Interior Mass UIMC Values:**Interior Mass¹¹ – Surfaces Exposed on One Side¹³**

			Unit
			Interior
			Mass
Material	Surface Condition	Thickness (inches)	Mass Capacity
Concrete	Exposed ⁴	2.00	3.6
		3.50	4.6
		6.00	5.1
	Covered ²	2.00	1.6
		3.50	1.8
		6.00	1.9
Lightweight Concrete ⁹	Exposed	0.75	1.0
		1.00	1.4
		1.50	2.0
		2.00	2.5
	Covered	0.75	0.9
		1.00	1.0
Solid Wood ⁹	Exposed	1.50	1.2
		3.00	1.6
Tile ^{3,9}	Exposed	0.50	0.8
		1.00	1.7
		1.50	2.4
		2.00	3.0

Masonry ^{4,9}	Exposed	1.00	2.0
		2.00	2.7
		4.00	4.2
Adobe ⁹	Exposed	4.00	3.8
		6.00	3.9
		8.00	3.9
Framed Wall	0.50" Gypsum	na	0.0
	0.63" Gypsum	na	0.1
	1.00" Gypsum	na	0.5
	0.88" Stucco	na	1.1
Masonry Infill ^z	0.50" Gypsum	3.50	1.3

Table 3-2 continued on next page.

Table 3-2b: Interior Mass UIMC Values:

Interior Mass¹¹ – Surfaces Exposed on Two Sides^{5,13}

		Unit	
		Mass	Interior
		Thickness	Mass
Material	Surface Condition	(inches)	Capacity
Partial Grout Masonry ⁴	Exposed ⁴	4.00	6.9
		6.00	7.4
		8.00	7.4
Solid Grout Masonry ^{4,6}	Exposed	4.00	8.3
		6.00	9.2
		8.00	9.6
Adobe	Exposed	4.00	7.6
		12.00	7.8
		16.00	7.6

Solid Wood/	Exposed	3.00	3.3
Logs		4.00	3.3
		6.00	3.3
		8.00	3.3
Framed Wall	0.50" Gypsum	na	0.0
	0.63" Gypsum	na	0.2
	1.00" Gypsum	na	0.9
	0.88" Stucco	na	2.1
Masonry Infill ^z	0.50" Gypsum	3.50	2.6
<hr/>			
Notes follow Table 3-3.			

Table 3-3: Exterior Wall Mass UIMC Values and Exterior Mass Factors¹³

Material	Surface Condition	Mass		Unit	
		Thickness (inches)	Wall U-value	Interior Mass Capacity	Exterior ⁸ Mass Factor
Partial Grout Masonry ⁴	Exposed ⁴	4.00	0.68	0.9	1.1
			0.58	1.0	1.0
		6.00	0.54	1.3	1.3
			0.44	1.5	1.1
		8.00	0.49	1.5	1.3
			0.38	1.7	1.2
	Furred ¹⁰	4.00	0.40	0.5	0.9
			0.30	0.5	0.7
			0.20	0.5	0.5
			0.10	0.5	0.3
			0.08	0.5	0.2
		6.00	0.40	0.9	1.2
			0.30	0.6	1.0
			0.20	0.5	0.7
			0.10	0.5	0.4
			0.08	0.5	0.3
		8.00	0.30	0.8	1.0
			0.20	0.5	0.7
Solid Grout Masonry ^{4,6}	Exposed	4.00	0.79	1.0	1.4
		6.00	0.68	1.5	1.9
		8.00	0.62	1.8	2.1
	Furred ¹⁰	4.00	0.40	0.5	1.0

	0.30	0.5	0.8
	0.20	0.5	0.6
	0.10	0.5	0.3
	0.08	0.5	0.3
6.00	0.40	0.7	1.4
	0.30	0.5	1.1
	0.20	0.5	0.7
	0.10	0.5	0.4
	0.08	0.5	0.3
8.00	0.40	0.8	1.5
	0.30	0.6	1.2
	0.20	0.5	0.8
	0.10	0.5	0.4
	0.08	0.5	0.3
Table 3-3 continued on next page			

Table 3-3: Exterior Wall Mass UIMC Values and Exterior Mass Factors¹³

Material	Surface Condition	Mass Thickness	Wall	Unit Interior	Exterior ⁹
		(inches)	U-value	Mass Capacity	Mass Factor
Solid Wood/ Logs	Exposed ¹	3.00	0.22	0.7	0.5
		4.00	0.17	0.9	0.6
		6.00	0.12	1.1	0.6
		8.00	0.093	1.2	0.4
		10.00	0.075	1.3	0.3
		12.00	0.063	1.3	0.3
Wood Cavity Wall ¹²	Exposed	3.00 ¹²	0.11	1.1	0.5
			0.065	1.3	0.3
			0.045	1.4	0.2
Adobe	Exposed	8.00	0.35	2.1	1.5
		16.00	0.21	2.8	0.8
		24.00	0.15	3.1	0.5
Masonry Veneer ⁴	Framed Wall	4.00	0.10	na	0.3
			0.08	na	0.3
			0.06	na	0.2
Adobe Veneer	Framed Wall	4.00	0.10	na	0.4
			0.08	na	0.3
			0.06	na	0.2

Notes For Tables 3-2 and 3-3:

1. "Exposed" means that the mass is directly exposed to room air or covered with a conductive material such as ceramic tile.
2. "Covered" includes carpet, cabinets, closets or walls.
3. The indicated thickness includes both the tile and the mortar bed, when applicable.
4. Masonry includes brick, stone, concrete masonry units, hollow clay tile and other masonry.

5. ~~The unit interior mass capacity for surfaces exposed on two sides is based on the area of one side only.~~
 6. ~~"Solid Grout Masonry" means that all the cells of the masonry units are filled with grout.~~
 7. ~~The indicated thickness for masonry infill is for the masonry material itself.~~
 8. ~~Use the Exterior Mass value for calculating Exterior Wall Mass.~~
 9. ~~Mass located inside exterior walls or ceilings may be considered interior mass (exposed one side) when it is insulated on the exterior with at least R-11 insulation, or a total resistance of R-9 including framing effects.~~
 10. ~~"Furred" means that 0.50-inch gypsum board is placed on the inside of the mass wall separated from the mass with insulation or an air space.~~
 11. ~~When mass types are layered, e.g. tile over slab-on-grade or lightweight concrete floor, only the mass type with the greatest interior mass capacity may be accounted for, based on the total thickness of both layers.~~
 12. ~~This wall consists of 3 inches of wood on each side of a cavity. The cavity may be insulated as indicated by the U-value column.~~
13. ~~Values based on properties of materials listed in 1993 ASHRAE Handbook of Fundamentals.~~

~~APPENDIX B~~

~~The Contents of Appendix B Have Been Deleted.~~

~~Appendix B is~~

~~Reserved for Future Use for Sample CALRES Test Run
Files and Input Descriptions for Tests 00 to 15.~~

~~These sample files will be added for information purposes
only, and will not be adopted as regulations.~~